Prepared by
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IN THE UNITED STATES DISTRICT COURT
MIDDLE DISTRICT OF TENNESSEE
NASHVILLE DIVISION

TENNESSEE CLEAN WATER NETWORK and TENNESSEE SCENIC RIVERS ASSOCIATION,	)	No. 3:15-cv-00424
Plaintiffs,	)	Chief Judge Waverly Crenshaw
v.	)	Magistrate Judge Holmes
TENNESSEE VALLEY AUTHORITY,	)	
Defendant.	)	

<u>DECLARATION OF CHRIS GROVES, Ph.D., P.G. REGARDING RESULTS OF HYDROGEOLOGIC INVESTIGATIONS WITH RESPECT TO THE FATE AND TRANSPORT OF COAL COMBUSTIAN RESIDUALS IN GROUNDWATER AND THE CUMBERLAND RIVER AT THE TVA GALLATIN FOSSIL PLANT, TENNESSEE THROUGH SEPTEMBER 27, 2017</u>

1. I, Chris Groves, am over 18 years of age. I make the following statements pursuant to 28 U.S.C. § 1746. If called upon to testify in this matter, I would testify under oath to the following statements:

2. This declaration summarizes a hydrogeologic analysis of conditions at the Tennessee Valley Authority's (TVA) Gallatin Fossil Plant (GAF) with respect to the fate and transport of coal combustion residuals (CCR) into groundwater and the Cumberland River. While data from the previous several decades of study by TVA and its contractors have provided a clear and consistent picture, which I described previously in detail (Groves, 2015, 2016a, 2016b, 2016c, 2016d), new data emerging from a 2016-17 Environmental Investigation Plan (EIP) action have dramatically increased the detailed understanding of these conditions.

3. While prior to the EIP it was already beyond any doubt that i) groundwater has been and continues to be contaminated by CCR at Gallatin, ii) the Cumberland River had been contaminated previously by CCR flowing through one or more conduits in the karst drainage system beneath the facility, and iii) it is very highly likely that this contamination of the river continues today, the new data **absolutely confirm that the Cumberland River continues to be contaminated by CCR through the karst drainage system**. The new data are also consistent with an earlier predication made by TVA (Young, 1992, p. 39) that "heavy metal concentrations will eventually exceed" primary drinking water standards in groundwater at GAF, and likely spread beyond the northern property boundary to contaminate domestic wells there.

4. **The EIP data on groundwater flow and water/soil contamination demonstrate an urgent need to remediate these conditions as quickly as possible.**

5. The EIP investigation identified several confirmed unpermitted groundwater discharges (RM 240.7 and CV2W5) through which CCR contamination is flowing into the Cumberland River from the Ash Pond Complex. Four other likely unpermitted discharges (CV1W9, CRW17, CRW19, and CRE1) have also been identified.

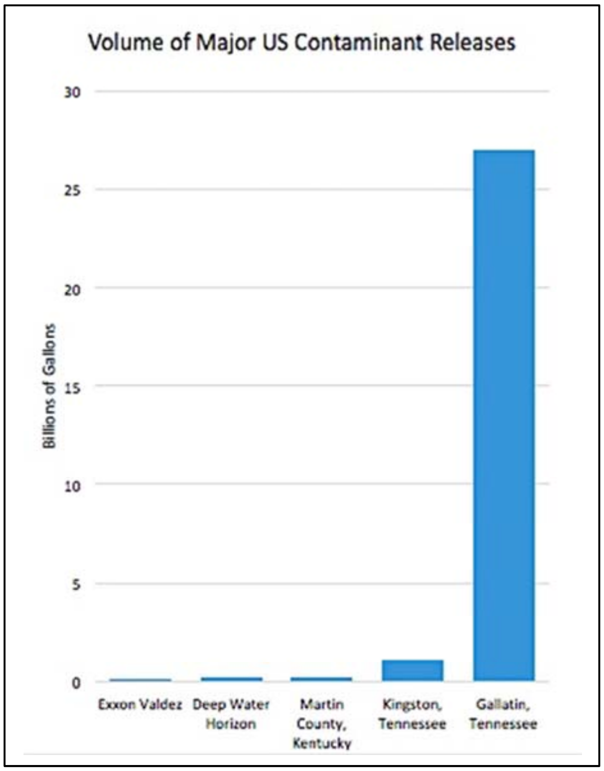

Figure 1. Major US contaminant spills. Data from Peterson (2003); Valentine et al. (2014); Bell and York (2010); Ruhl et al. (2010); Groves (2015). EIP data now confirm that the value shown for Gallatin is a significant underestimation. Figure from Groves (2016c, p. 3).

6. RM 240.7, where CCR-contaminated groundwater is discharging from the bed of and into the Cumberland River, is the exit of an underground river that I identified and described in previous reports (Groves, 2015; 2016a; 2016b; 2016c; 2017d) based on several concordant lines of hydrogeologic data. It is through this karst conduit that TVA lost some 27 billion gallons of coal ash slurry from the Ash Pond Complex between 1970 and 1978 (Figure 1). Although in terms of the science-based understanding of environmental contamination at GAF concern has been expressed about definitively identifying when the relevant pollutants entered the water , the EIP data now confirm that CCR has been flowing through the karst aquifer and directly into the Cumberland River continuously for the past 47 years since the Ash Pond Complex was placed into service in 1970.

7. This declaration is divided into two sections, including i) the most relevant new results from the recent EIP data, and ii) a review of previous hydrogeologic data that provide context for interpreting those results.

8. Figure 2 shows the location of RM 240.7 along with the location I predicted in July 2016 for the discharge point of the main karst conduit into the Cumberland River, based on other hydrogeologic data, that provides a direct hydrologic connection between the Ash Pond Complex and the Cumberland River.

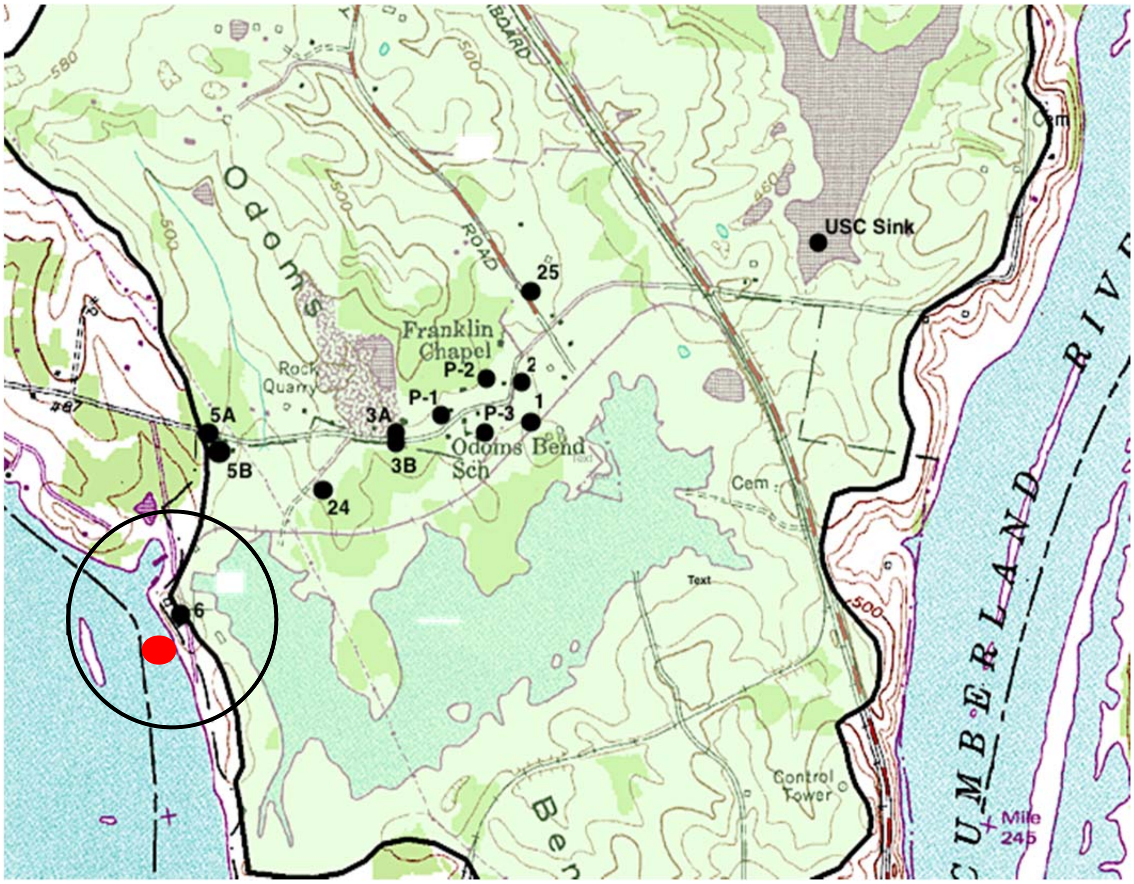

Figure 2. map from an earlier report (Groves, 2016c, Figure 7) showing the area within which I predicted the outlet of the main underground river draining the Ash Pond Complex to be, based on several concordant lines of hydrogeologic data. The recently discovered location of RM 240.7 is indicated in red.

9. Samples from RM 240.7 at the bed of the Cumberland River taken between December 15, 2016 and June 27, 2017 had concentrations of dissolved boron, which has been identified as a good CCR indicator for Gallatin (Young, 1992), more than 200 times that of boron concentrations higher above in the water column. Chloride, fluoride, arsenic, and manganese concentrations ranged from about 10 to 40 times higher, and molybdenum ranged from about 20 to 75 times higher.

10. The temperature of the water emerging from RM 204.7 during both summer and winter sampling had a narrow range of 62.4-64.0^{o}F, which was about 14^{o} warmer than the ambient river temperature on December 15, 2016. This uniform temperature, even though the ambient river

water temperature fluctuates with the seasons, is a clear indicator of the ongoing groundwater discharge.

11. At another location, new EIP data report a water sample (results provided September 5, 2017) at the unauthorized discharge point Seep 13 on the bank of the Cumberland River that had an arsenic level of 619 parts per billion (ppb), which exceeds TDEC's Maximum Contaminant Level (MCL) of 10 ppb by more than 61 times.

12. Soil samples at Seep 13 (results provided September 5, 2017) on the bank of the Cumberland River had arsenic over 40,000 ppb and lead over 13,000 ppb, both of which exceed the Tennessee Department of Environmental and Conservation's (TDEC) clean-up levels, based on US Environmental Protection Agency Regional Screening Levels (RSL). (<https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-november-2017>)

13. Water samples from at least eleven wells collected as part of the EIP between June 12 and 20, 2017, including three immediately adjacent to the Cumberland River and two along GAF's northern property boundary (Figure 3), had concentrations of contamination that exceed MCLs including antimony, arsenic, beryllium, cadmium, chromium, fluoride, nickel and thallium.

14. These new data confirm the earlier prediction by TVA (Young, 1990, p. 39) that heavy metals would migrate through the groundwater of, and likely beyond the boundary of, GAF.

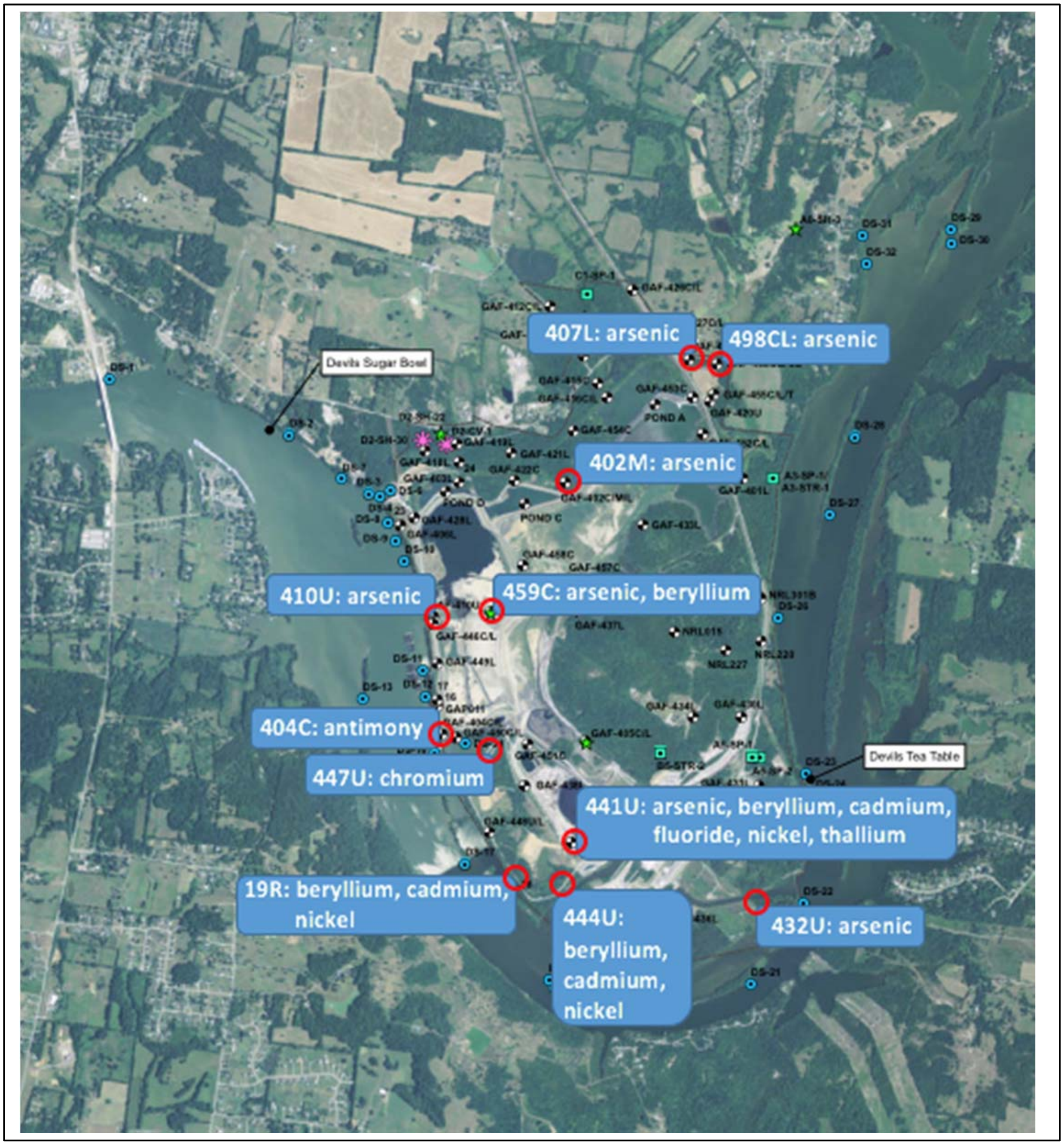

Figure 2. Wells at GAF with groundwater exceeding MCLs for heavy metals or other contaminants in June 2017. Precise locations of several wells are not shown on the base map used, and in those cases (19R, 444U, 432U, 447U) red circles show approximate locations.

15. Although by 1990 boron, described by Young (1990, p. 21) as "a good leachate indicator at Gallatin," had spread through the groundwater of most of the peninsula, heavy metals had not.

16. However, noting (p. 39) that "the migration rate for boron is faster than other leachate constituents such as heavy metals" he predicted that their contaminant plumes would lag behind the boron, and that "heavy metal concentrations will eventually exceed" primary drinking water standards at the domestic wells north of GAF.

17. As Young predicted, heavy metal contamination plumes have now spread throughout the groundwater at GAF (Figure 3 and Table 1) and there is no reasonable hydrogeologic mechanism that would cause one to expect that this process ends at the GAF boundary.

CCR Chemical of Concern	Oct 2016	Nov 2016	Dec 2016	Jan 2017	Feb 2017	Mar 2017	Apr 2017	May 2017	Jun 2017	Total
Antimony	0	0	1	1	0	1	1	1	1	6
Arsenic	0	7	10	8	8	8	3	6	8	58
Barium	0	0	1	0	0	0	0	0	0	1
Beryllium	2	2	4	3	4	5	4	3	4	31
Cadmium	2	2	3	2	2	3	3	4	3	24
Chromium	0	0	3	1	0	1	0	0	1	6
Fluoride	0	1	1	1	1	2	1	2	1	10
Nickel	2	2	4	4	3	5	3	3	3	29
Selenium	0	1	2	0	2	1	2	1	0	9
Thallium	0	1	3	1	1	1	1	1	1	10
Total	6	16	32	21	21	27	18	21	22	184

Table 1. Contaminant concentrations that exceed MCLs in groundwater at GAF from October 2016 through June 2017. In addition, there were 129 detections of boron, considered an effective CCR indicator for Gallatin (Young, 1990), in excess of 3,000 parts per billion.

18. These data clearly provide detailed, credible evidence that current leakage pollutant concentrations in the amounts observed today.

19. The remaining paragraphs provide an overview of the most relevant hydrologeologic studies at GAF, explaining how both the previous and new EIP data present a compelling and

consistent story that cannot be plausibly explained by any other scenario than the one described above.

20. I am a licensed Professional Geologist in Tennessee with more than 30 years of professional experience in karst hydrogeology. I earned a PhD in Environmental Sciences at the University of Virginia in 1993 and have since developed an international research program with fieldwork in 25 countries. In January, 2017 I received China's highest honor for foreign scientists from China's President Xi Jinping for "great contributions to China's hydrogeology and karst geology fields."

21. I have served as co-Leader for several karst-related United Nations scientific programs, and serve on the Governing Board of the International Research Center on Karst under the Auspices of UNESCO. I am an Associate Editor of *Hydrogeology Journal*, and have published in the field's leading peer-reviewed journals, including *Groundwater, Water Resources Research, Journal of Hydrology, Geomorphology, Journal of Contaminant Hydrology.*

22. Since 1982 I have explored, mapped, and otherwise studied caves, done karst aquifer evaluations and performed groundwater dye traces in the principal karst regions of the Tennessee, including Central Basin where Gallatin is located.

23. The Tennessee Valley Authority (TVA) Gallatin Fossil Plant (GAF) is located on Odom's Bend on the north bank of the Cumberland River near Gallatin Tennessee. Coal combustion residues (CCR) were disposed of from the beginning of CCR production until 1970 at a 57-acre ash disposal facility today known as Non-Registered Site #83-1324 (NRS). When the NRS reached capacity in 1970 CCR waste was rerouted to a collection of larger basins to the northwest collectively called the Ash Pond Complex where disposal continues today.

24. It is well established that the bedrock in which Odom's Bend has developed forms a geologic environment called *karst* topography (Groves, 2015, 2016a, 2016b, 2016c, 2016d; Kutschke, 2016; Perry, 2016; Lang, 2016 and references therein).

25. Because of the typically high permeability of karst aquifers along with the ease and rapidity with which contaminants and enter and move through them, these groundwater systems are extremely vulnerable to contamination. This is the case for the karst aquifer beneath GAF.

26. TVA reported as early as 1979 (Young and Carden, 1979) that "The Gallatin Steam Plant ash pond has a history of leakage problems which has created groundwater contamination concerns." After an extensive review of conditions at the Ash Pond Complex, Stantec (2009) recommended that "Long-term strategies relative to plant-wide karst subsurface conditions should be developed, including consideration to installing lining systems beneath all ponds…" A TVA Expert Witness (Lang, 2016) wrote that "Considering the karst region and geology of the GAF, there does not exist a scenario in which karst activity can be eliminated."

27. In November, 2014 the Southern Environmental Law Center gave notice of its intent to sue for violations, among others, that TVA has allowed "unpermitted pollutant discharges to flow from the coal ash ponds and former waste disposal sites at the Gallatin Plant directly into the Cumberland River, as well as into groundwater that is hydrologically connected to the Cumberland River."

28. In November, 2015 an Agreed Temporary Injunction was ordered in the related state court action that required TVA to develop an Environmental Investigation Plan (EIP) to collect additional data to characterize the hydrogeology at GAF. TVA submitted an EIP in March 2016 to the Tennessee Department of Environment and Conservation (TDEC).

29. In May 2016, TDEC requested a revised EIP from TVA to include additional methods for the study of karst groundwater flow systems.

30. A revised EIP was submitted by TVA to TDEC in June 2016. Work on the environmental investigation commenced in 2016 and, to my understanding, is ongoing as of the date of this declaration.

31. For purposes of this declaration the abbreviation EIP is used to refer to the work performed under the auspices of TVA's Environmental Investigation Plan, as well as to the plan itself.

32. The following sections of this declaration summarize results of the ongoing EIP work that have been made available to me as of September 26, 2017, and which include 1) water table elevation data, 2) groundwater tracing data using three independent tracers: a) fluorescent dyes, b) conductivity, and c) temperature, and 3) water and soil quality sampling.

33. It is my professional opinion that the results of the EIP that I have reviewed are wholly consistent with, and provide additional detail in support of, the conceptual hydrogeologic model that I have described based on previously collected data (Groves, 2015, 2016a, 2016b, 2016c, 2016d and references cited therein).

34. The EIP has generated a very large amount of data and therefore this summary must contain a subset of this information. The information I have chosen to present represents data that show, in combination with the previous decades of data, a clear and consistent description of relevant hydrogeologic conditions at GAF. I affirm here that here is no selectivity or "cherry picking" to show a particular outcome. There is simply one story at GAF and EIP data confirm this.

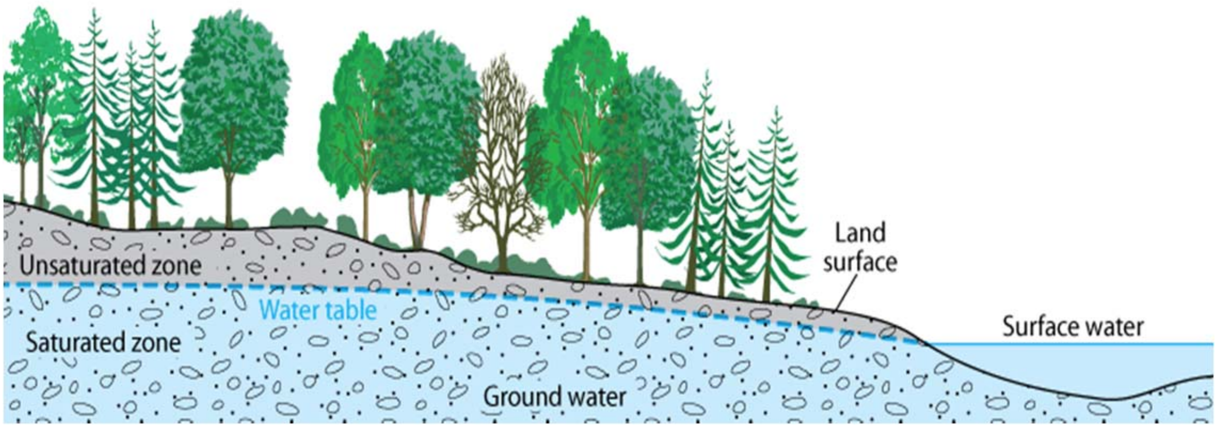

Figure 3. Generic profile showing typical underground water conditions, where the water table separates the unsaturated zone above from the saturated zone, below. Groundwater moves from high to low areas of the water table. This is broadly representative of the conditions at GAF except for not showing karst features (US Geological Survey, 2016).

35. To assist in understanding the EIP data I provide here a small amount of critical background. In relatively simple settings like at the NRS and Ash Pond Complex, underground water can be divided into two components: the unsaturated zone and the saturated zone which lies beneath it. Figure 2 shows a generic illustration of these. Rainfall infiltrating the ground moves downward through the soil and upper bedrock, through air-filled fractures or other spaces through which the water moves downward towards the water table. The water table represents the top of the saturated zone, within which all spaces are completely filled with water. The term *groundwater* refers to "subsurface water that occurs beneath the water table in soils and geologic formations that are fully saturated" (Freeze and Cherry, 1979), and groundwater flows from high areas of the water table towards lower areas. In Figure 4 groundwater flows from the hilly area on the left towards the lake on the right. Similarly, in general, at GAF groundwater flows from the central area of Odom's Bend peninsula towards and into the Cumberland River.

36. The hydrogeologic conditions at Odom's Bend, compared with numerous karst systems that I have studied through the world, are relatively simple.

37. One simple, fundamental fact is that the water table in the Ash Pond Complex is higher than the bottom of the ash. This means that the ash is saturated with groundwater.

The following sections describe the previous and EIP water table data. Additional groundwater wells have been drilled in the Ash Pond Complex as part of the EIP work to augment the wells already there.

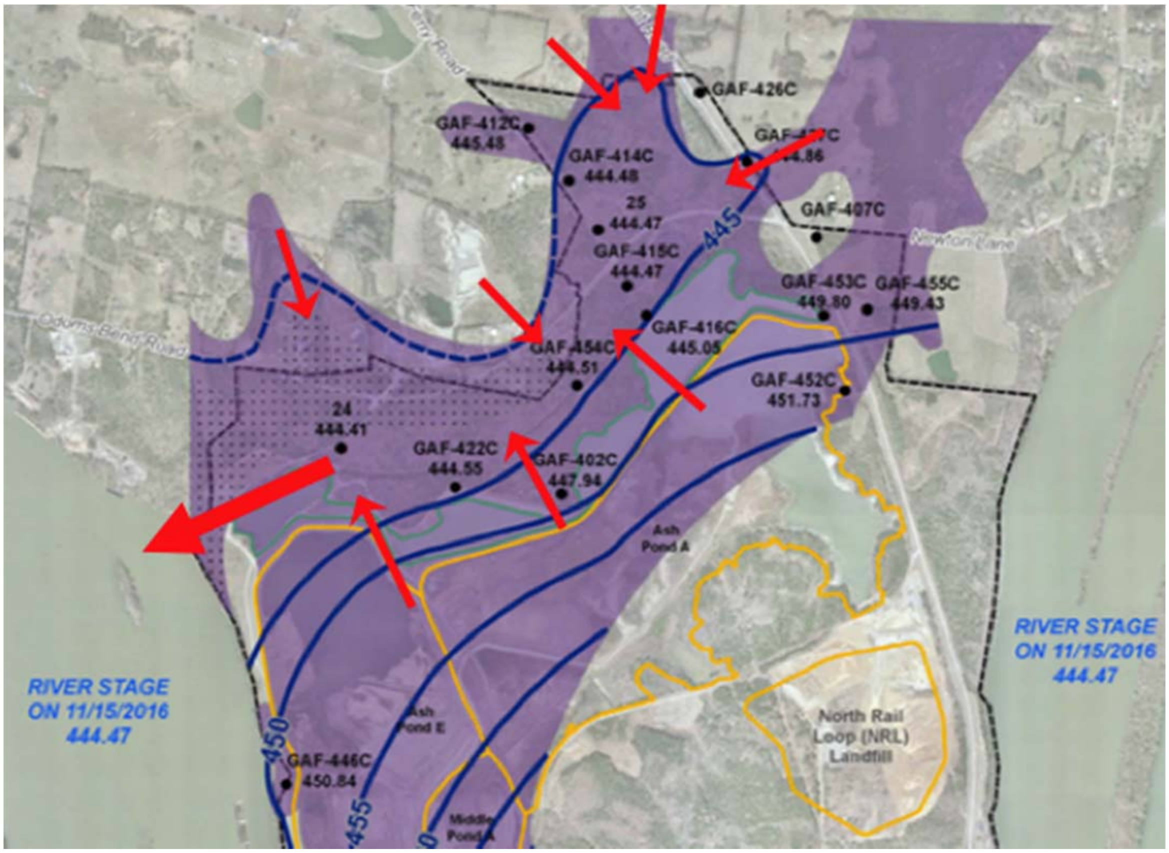

Figure 5. Water table elevations based on EIP wells drilled into the Carters limestone. Approximate directions of groundwater flow are shown in red. Groundwater from the Ash Pond Complex is flowing into the clearly defined groundwater trough and from there westwards to the Cumberland River.

Figure 5 shows EIP data for the water table for wells drilled into the Carters Limestone. The blue lines show the elevation of the water table and as groundwater flows from high to low water table elevations, the red lines are the associated directions of groundwater flow. It is evident that in the vicinity of the Ash Pond Complex, contaminated groundwater is flowing from the Ash Pond Complex, to the north into a well-defined groundwater trough that lies to the north of the

Ash Pond Complex, and then westward to the Cumberland River. TVA's Expert Witness Elizabeth Perry (2016) wrote "If CCR constituents were released from the ponds into groundwater, in the absence of more comprehensive information about hydraulic gradients, it is not possible to understand where that groundwater may go. (For example, groundwater could flow directly west to the River, or it could first move northward and then westward, and the direction may vary depending on location.)" The EIP now confirms that contaminated groundwater from the Ash Pond Complex moves north and then west to the river. It is important to note that Perry's (2016) statement above contains a misconception when she says "If CCR constituents were released from the ponds into groundwater…" as this doesn't make sense. The water in the ponds and the groundwater are a continuous body of the same water.

38. A simpler version of the same groundwater trough is shown in Figure 6. I had earlier laid

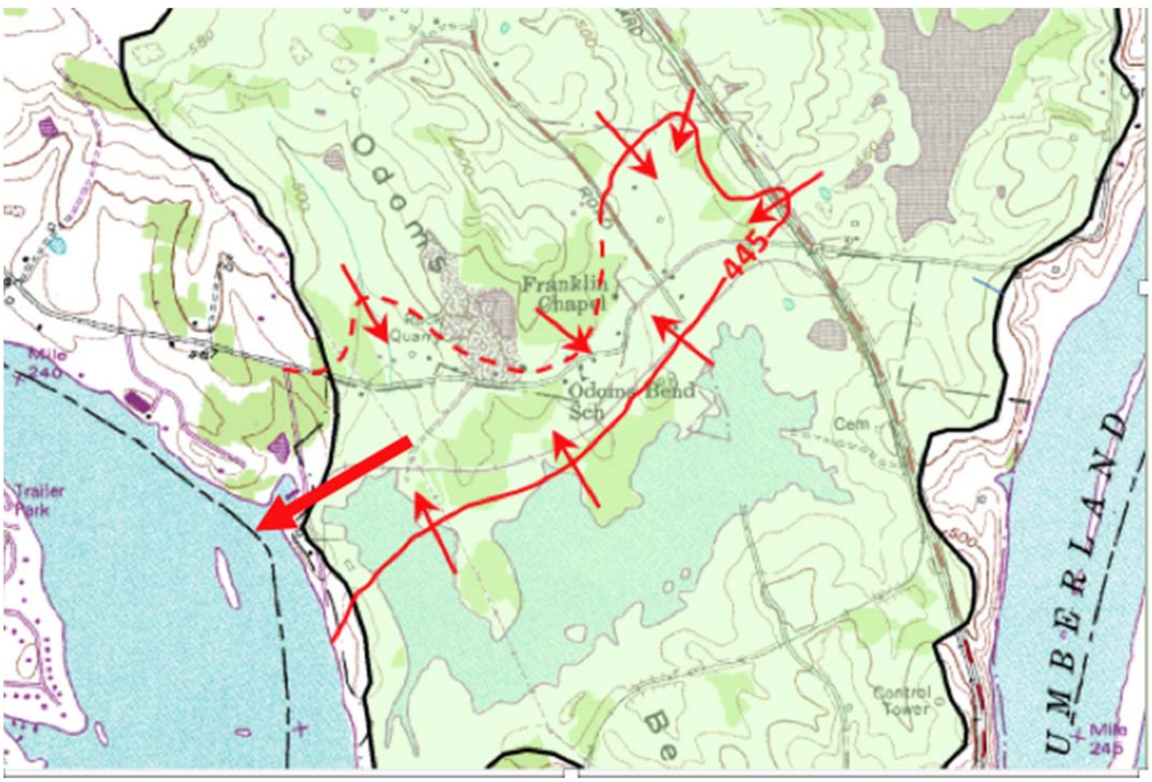

Figure 6. Simplified map of groundwater flow directions of groundwater flow from the Ash Pond Complex into the clearly defined groundwater trough and from there westwards to the Cumberland River

out several independent, consistent lines of evidence from earlier TVA studies that show that a major karst conduit with an underground river receives groundwater from the Ash Pond Complex. The water from the Ash Pond complex flows into the trough, and then turns and flows along the axis of this trough in a southwesterly direction to the Cumberland River (Groves, 2016c).

Dye Tracer Studies.

39. Groundwater flow tracing using fluorescent dyes as part of the EIP has confirmed the location of this underground river and that it is indeed flowing into the Cumberland River where it was earlier predicted to (Groves, 2016c). The dye tracing work is described in some detail below.

40. In this work the pathways of groundwater flow are mapped out by injecting dyes into groundwater at one location and detecting it at one or more other locations. I am able to describe these methods and interpret the results as I have designed and conducted many such groundwater tracing experiments in the last 35 years. I currently direct the Crawford Hydrology Laboratory, a nationally leading laboratory specializing in groundwater tracer tests.

41. At GAF, although this groundwater tracing work is ongoing, it has already produced clear, unequivocal, and critical results.

42. As of May 31, 2017, six different dyes have been introduced into the karst aquifer at GAF at various sinking streams and wells. About 130 locations are being monitored—very thorough coverage of the peninsula—for dye using standard techniques that I have reviewed (Figure 7).

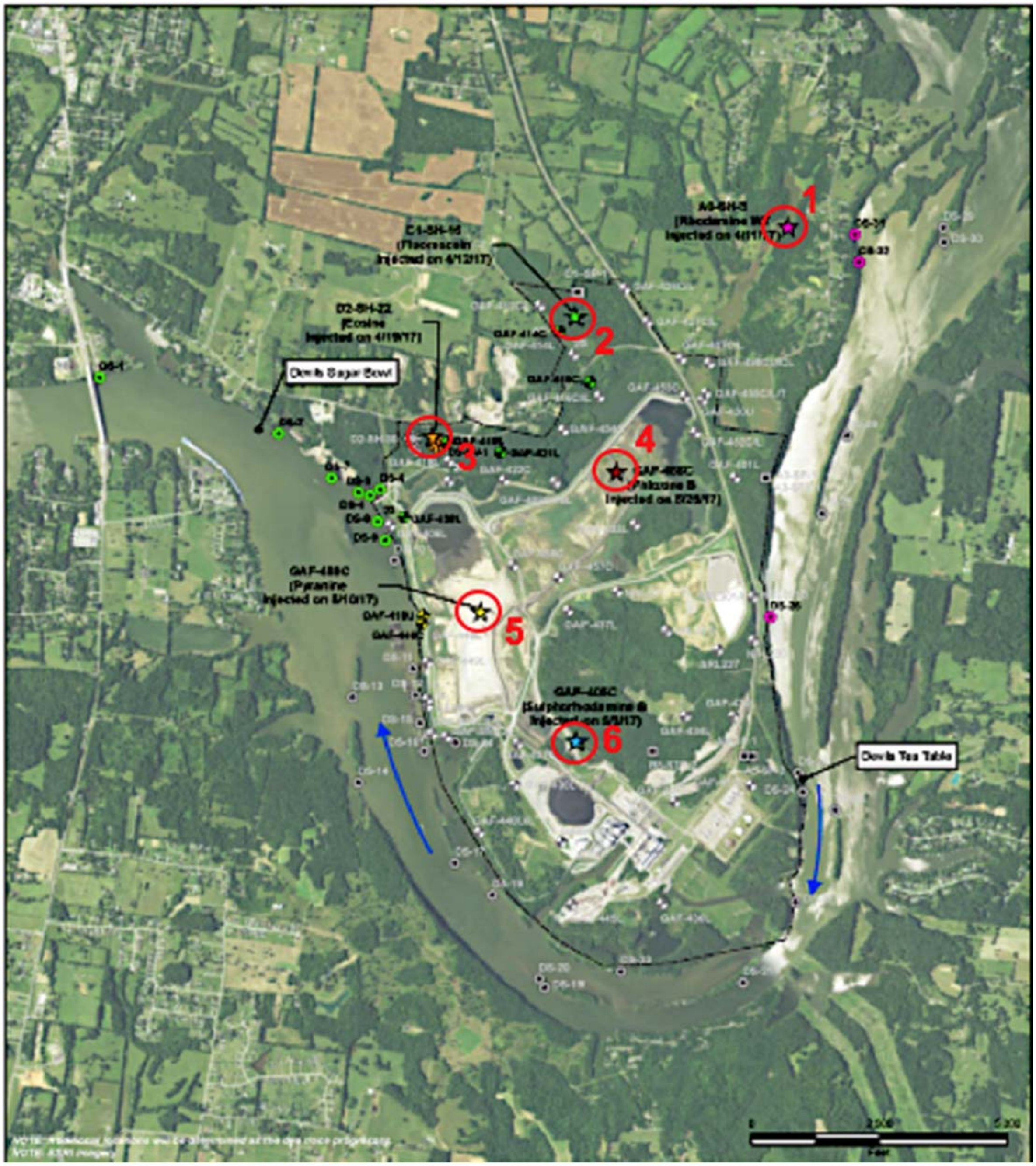

Figure 7. Injection and sampling locations for groundwater traced with fluorescent dyes at GAF. Injection locations are circled in red and activated dye receptors are installed and then replaced weekly at each of the sampling locations (see Figure 8).

43. The dye is not detected visually, but instead small mesh bags called containing activated charcoal "dye receptors" (Figure 8) that are installed at each of the monitoring locations. Different dyes are introduced at the injection points and the dye receptors are replaced

periodically, in the GAF EIP case about weekly, and the charcoal is analyzed for the presence of the dyes in the laboratory.

44. Dyes are used not so much because they are brightly colored (Figure 9), but because they can be easily detected in the charcoal at the lab at very low concentrations, are nontoxic, and relatively inexpensive.

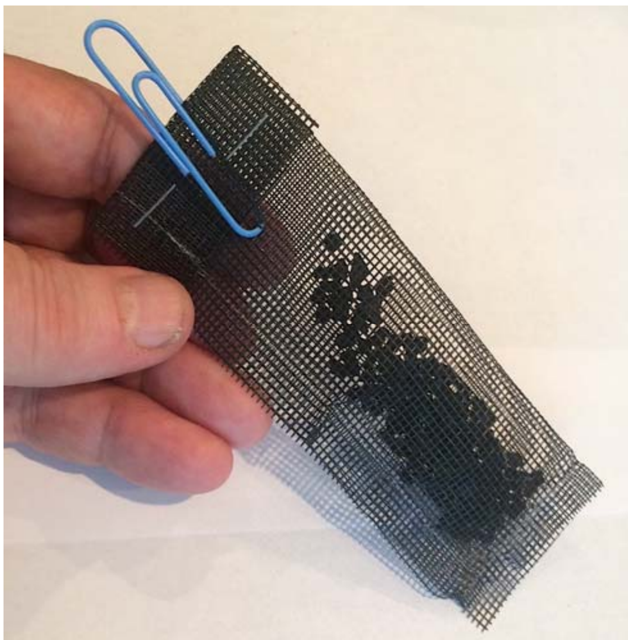

Figure 8. Charcoal dye receptor used for sampling water for tracing dyes. If dye flows past such a receptor, it absorbs into the charcoal, which can be analyzed in a laboratory.

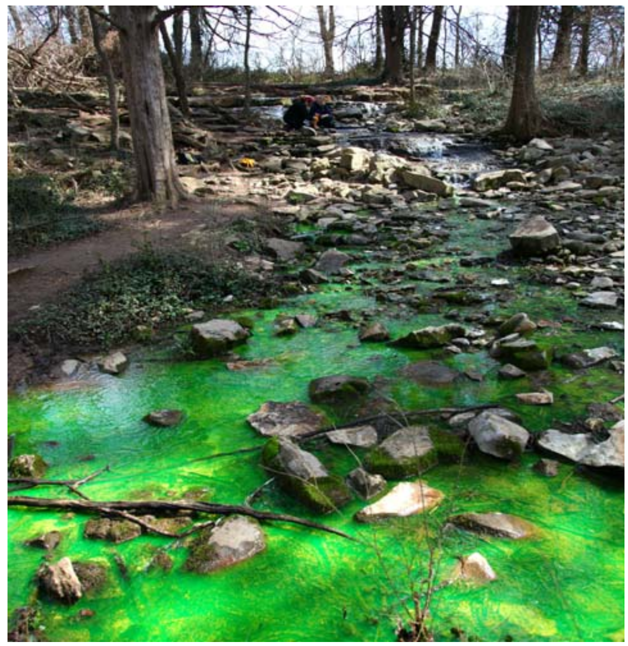

Figure 9. A photograph, taken by me at another location, provides an example of injecting fluorescent groundwater tracing dye into a sinking stream. This photo is for illustration purposes and not of a trace at GAF, but is one of the dyes being used in the EIP , Fluorescein.

45. A set of groundwater tracer tests using artificially introduced fluorescent dyes is underway at GAF and as of this writing of the six that have been initiated, two have been completed (1 and 2), one has partial results (3), and, to my knowledge, no results are have yet been obtained for the other three (4-6). In the case of traces 4-6 no inferences can be drawn from

the lack of results so far as the speed at which the dyed groundwater moves, and therefore the length of time required to reach monitoring locations, is highly variable.

46. Dye trace 1 has been completed, but is of limited relevance for understanding groundwater flow at GAF. Dye was injected into the northwest “arm” of the Upper Sinkhole Complex (Upper Glover’s Pond) on April 11, 2017 and was detected in the Cumberland River on the east side of Odom’s Bend (Figures 7 and 10). This is not the main sinking stream draining the Upper Sinkhole Complex (USGS, 1955) but rather is local drainage from the area of that “arm” that that forms a small karst drainage system that is not relevant to the much larger karst aquifer system associated with the Ash Pond Complex.

47. The results of dye trace 2 confirm the location of the outlet of the karst aquifer system in the vicinity of the Ash Pond Complex at RM 240.7 through which groundwater is flowing into the Cumberland River (Figure 11). Dye was injected into a sinking stream at point 2 (Figure 7) on April 12, 2017. As would be predicted from the water table elevation data, the dye flowed with groundwater into the water table trough confirmed by the EIP and shown in Figures 3 and 4. This water flows through wells 414C/L, and from there to well 421L, and from there towards, and into, the Cumberland River. Although the exact location of RM 204.7 was not yet known at the time of dye trace 2, the dye came into the River and as it flowed downstream, the next dye receptor downstream from RM 204.7 was the first to receive the dye.

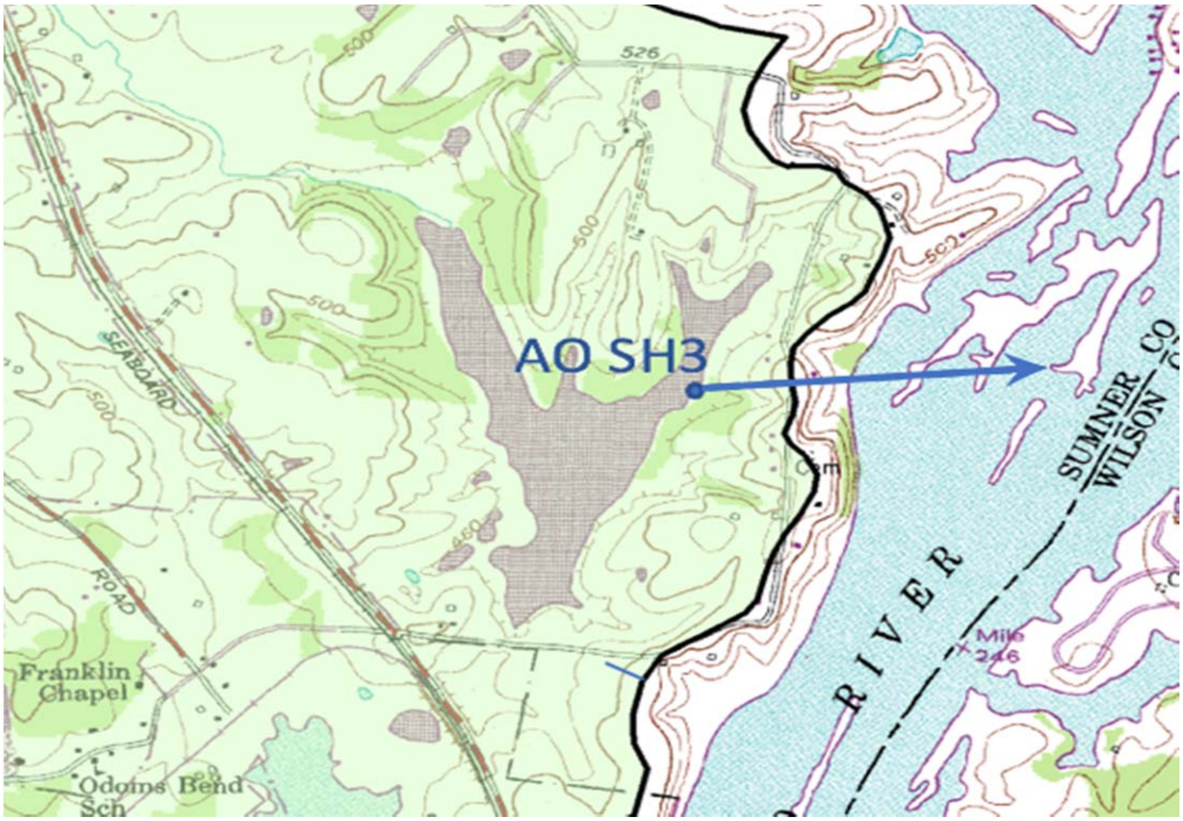

Figure 10. Dye trace from the northwest "arm" of the Upper Sinkhole Complex. This is local drainage from that "arm" and is not the main drainage point for the Upper Sinkhole Complex. It does reflect the fact that generally, the groundwater on the peninsula drains outward to the Cumberland River.

48. Dye for trace 3 was injected into a small sinking stream on April 19, 2017 (Figure 5), and has been detected at several cave and well sampling locations in the direction of the river, indicating that the water is flowing toward the river. I expect that the dye will continue to flow toward the Cumberland River and will eventually reach it.

49. Dye traces 4, 5, and 6 were initiated on May 3, 11, and 31 respectively in wells as shown on Figure 7, and as of the date of this statement, to my knowledge there have so far been no detections. As explained in paragraph 45, no conclusions can be drawn from this experiment in progress.

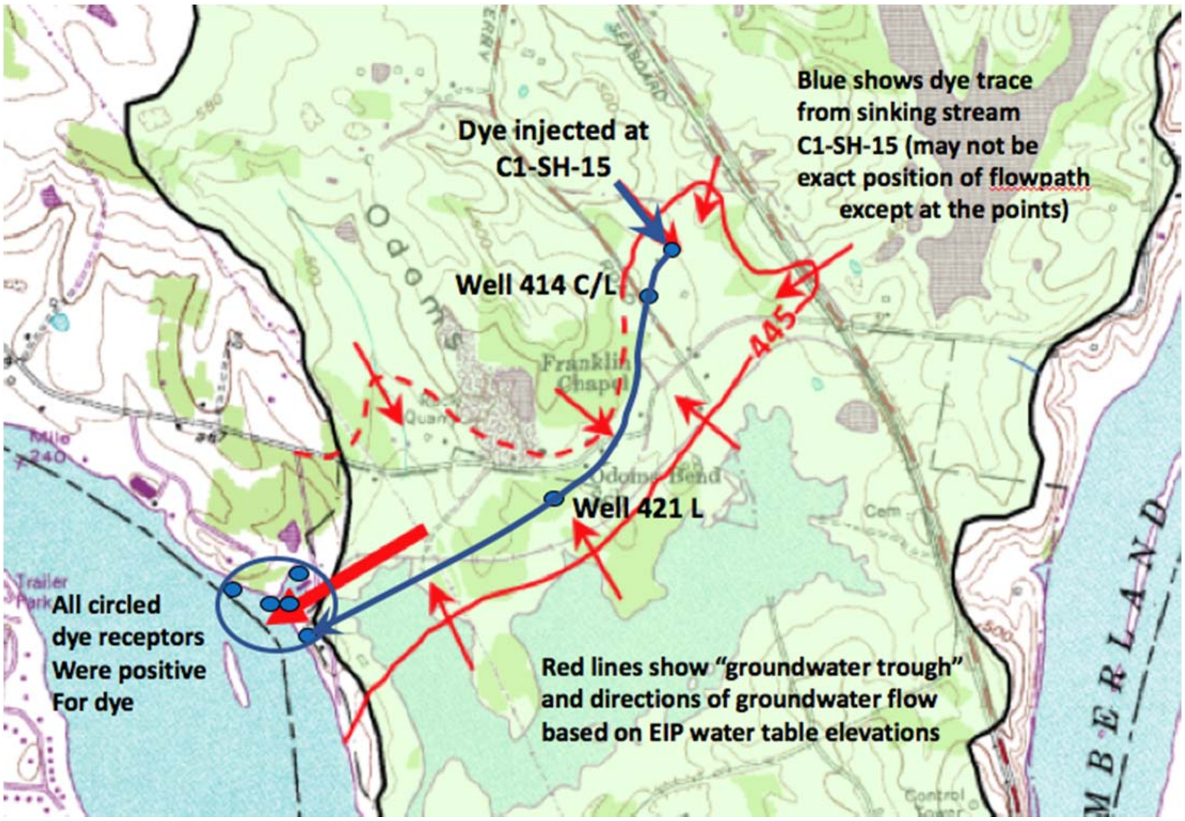

Figure 11. Route of dye trace 2 shows major flow path in the karst aquifer from GAF to the Cumberland River. This dye reached the river in the same place predicted by the EIP water level data.

<u>Conductivity Survey.</u>

50. A conductivity survey has been undertaken for water along the shore of Odom's Bend. Conductivity testing can easily measure water chemistry in a way that indicates the total concentration of dissolved ions in the water. In the context of the Cumberland River adjacent to GAF, water containing CCR has high conductivity and the relatively unpolluted water of the river is low. In this way, the concentrated ions of the high conductivity water from the coal ash ponds can serve as a tracer of CCR in a similar way to the dye.

Figure 4. Map generated through the EIP showing high conductivity "anomalies of interest" in the Cumberland River adjacent to the Ash Ponds. These show relatively high concentrations of ions indicative of CCR.

51. The data, shown in Figure 12, are quite simple to interpret. There are numerous high conductivity “anomalies of interest” along the western shore of Odom’s Bend adjacent to the ash ponds (Figure 12, note that north is to the left in this photo). Some these are concentrated in the vicinity of outfall the NRS.

<u>Temperature survey.</u>

52. Another *very* compelling data set has come from groundwater flow tracing in the EIP using temperature. Groundwater stays at approximately the same temperature year around. In nessee groundwater maintains a consistent temperature in the mid 50s Fahrenheit. The water at or near the surface of the Cumberland River at Old Hickory Lake, by contrast, fluctuates seasonally with air temperature, so that it is relatively warm in the summer and cold in the winter. This means that, in general, that groundwater is *warmer* than the surface river water in

the winter and *colder* than the surface river water in the summer.

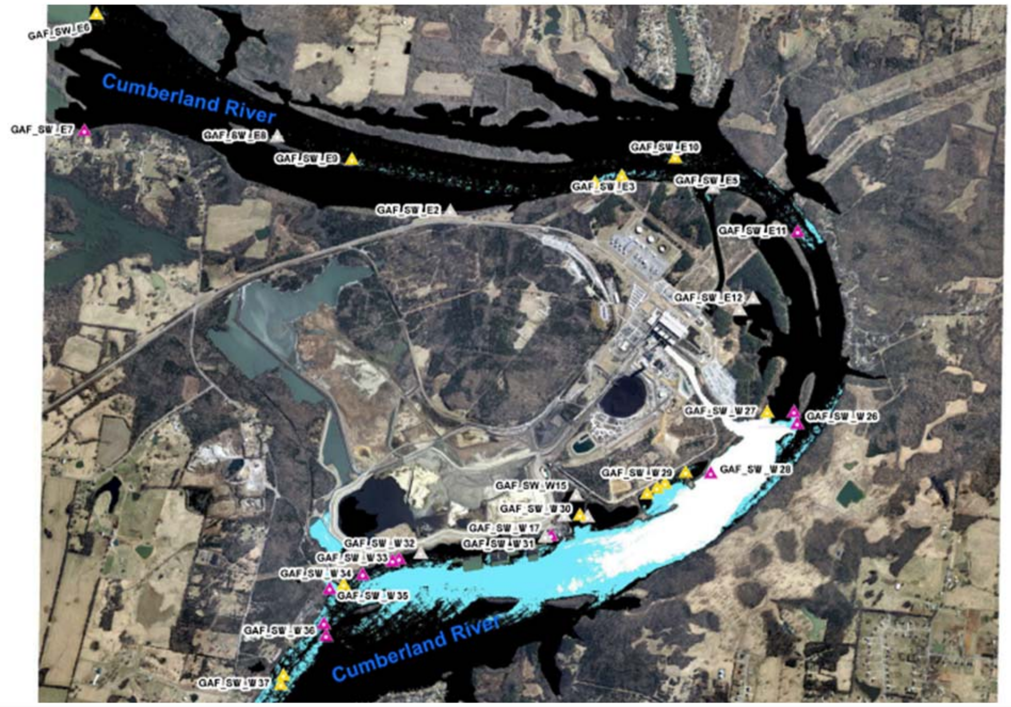

Figure 5. Wintertime thermal images taken as part of the EIP show water variations in water temperature of the Cumberland River at Odom's Bend. Note that north is to the left. There are numerous "thermal anomalies of interest" along the shoreline of Odom's Bend indicative of relatively warm groundwater entering the river.

53. Equipment that can make images that show temperatures was employed by air to make thermal images of the Cumberland River in summer (August 29-September 2, 2016) and winter (February 9, 2017) conditions. The numerous "thermal anomalies" that are apparent in the images (Figures 13 and 14) are indicative of groundwater flowing from the peninsula into the Cumberland River. Descriptions of the anomalies indicate several of special interest, some for a significant potential for karst activity, based on several lines of evidence including the strength of the anomaly, correspondence with conductivity anomalies, correspondence of winter and summer anomalies, position within the original river channel where natural springs may have been expected to be located, and correspondence with the locations of mapped sinkholes.

Figure 14. Summertime termal anomalies of interest in the Cumberland River. This map does not show the actual mapped colors representing the different temperature, but does show the mapped anomalies.

54. In summary, there is one story from these data: CCR at GAF has contaminated, and continues to contaminate, groundwater and the Cumberland River. It is urgent that remediation starts as soon as possible.

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CERTIFICATE OF SERVICE

I hereby certify that the foregoing Declaration of Chris Groves Regarding Results of Hydrogeologic Investigation with Respect to the Fate and Transport of Coal Combustion Residuals in Groundwater and the Cumberland River at the TVA Gallatin Fossil Plant was filed electronically on December 21, 2017, through the Court's Electronic Filing System. Notice of this filing will be sent by operation of the Court's electronic filing system to all parties indicated on the electronic filing receipt. Parties may access this filing through the Court's electronic filing system.

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